

Analysis of elliptical patch microstrip array antenna

Dr. RK Verma

Microwave Lab, Department of Physics, Agra College Agra, Uttar Pradesh, India

Abstract

In this communication an analysis of elliptical patch microstrip array antenna is presented. The Full Wave Analysis and Method of Moment have been applied to developed field equation and resonance frequency for elliptical shape antenna. In Full Wave Analysis we solve wave equation by the Mathieu Special function in combined form as well as separate (Radial and Cylindrical) form. But due to some mathematical complication we had to switch Method of moment analysis with the help of cavity model of Elliptical elements on thin dielectric substrates support only TM modes. The far field radiation patterns in the Oblate mode are obtained for E plane and H plane. A comparison of characteristics of circular and elliptical microstrip patch antenna printed on RT-duroid is also presented in this paper.

Keywords: elliptical patch microstrip array antenna, full wave analysis, mathieu special function, moment method

1. Introduction

The elliptical shape has several advantages like providing larger degrees of freedom and flexibility in the design, compare to the circular geometry. One of the prominent advantages is circular polarization which can be easily obtained by exciting the elliptical patch rather than rectangular or circular ones by means of the proper selection of feed position of the ellipse. To generate a circular polarization the feed point should be on a radial line positioned relative to the major axis where the positive side axis gives left-hand circularly polarized (LHCP) while the negative axis gives right-hand circularly polarized (RHCP) (Shen, 1981) ^[12]. Furthermore, the elliptic antenna offers greater flexibility in the design by utilizing the eccentricity and the focal length to fine tune the antenna to the desired performance.

Although there have been several methods used to analyze the regular patch geometries like circular, rectangular, triangular, etc. using spectral domain analysis (Harrington, 1968) ^[7], transmission line method, cavity model, resonant equivalent circuits and the method of moments (Shmna and Bhat, 1980; Baky and Deshpande, 1985) ^[13, 2] but they had the shortcomings of degrading accuracy as the thickness of the substrate increases in case of elliptical geometry (Long and McAllister, 1982; Long *et al.*, 1981; Lee and Chen, 1997) ^[10]. These numerical techniques take a significant amount of computational time, even when considering just one or two modes, thus making interactive design a difficult task. The more direct approach, Green's function approach, which is generally used for circular and rectangular patches (Hab'tshy *et al.*, 1987) ^[6], had not been applied to the EPA because a computationally efficient Green's function was not available. Though approximate solutions were devised by some researchers explained in (Bahl and Bhartia, 1990; Shen, 1981) ^[1, 12], these approximations are limited to small eccentricities and have dealt with the TM₁₁ mode only. It is, however, complicated to analyze the elliptical-patch geometry because of its unique elliptical characteristics.

2. Materials and Methods

2.1 Theory

The geometry of elliptical patch microstrip antenna is shown in figure 1. The elliptical patch of major axis '2a' and minor axis '2b' printed on RTduroid substrate of thickness 'h'.

The properties of the elliptic patch as a microstrip antenna have been investigated through extensive experimentation, though these properties have not been verified by any one general theory. In the present work we have tried two mathematical analysis (1) Full Wave Analysis and (2) Method of Moment with Cavity Model, to study the elliptical patch antenna (EPA).

E-Plane ($\varphi = 90^\circ$)

For Oblate Ellipse

$$E_r = E_\varphi = 0 \quad (1)$$

$$E_\theta = j \frac{k a^2 E_0 e^{-jkr}}{r} \left\{ \frac{J_1(ka \sin \theta)}{ka \sin \theta} \right\} \quad (2)$$

For Prolate Ellipse

$$E_r = E_\varphi = 0 \quad (3)$$

$$E'_\theta = j \frac{k b^2 E_0 e^{-jkr}}{r} \left\{ \frac{J_1(kb \sin \theta)}{kb \sin \theta} \right\} \quad (4)$$

H-Plane ($\varphi = 0$)

For Oblate Ellipse

$$E_r = E_\theta = 0 \quad (5)$$

$$E_\varphi = j \frac{k a^2 E_0 e^{-jkr}}{r} \left\{ \cos \theta \left[\frac{J_1(ka \sin \theta)}{ka \sin \theta} \right] \right\} \quad (6)$$

For Prolate Ellipse

$$E_r = E_\theta = 0 \quad (7)$$

$$E'_\varphi = j \frac{k b^2 E_0 e^{-jkr}}{r} \left\{ \cos \theta \left[\frac{J_1(kb \sin \theta)}{kb \sin \theta} \right] \right\} \quad (8)$$

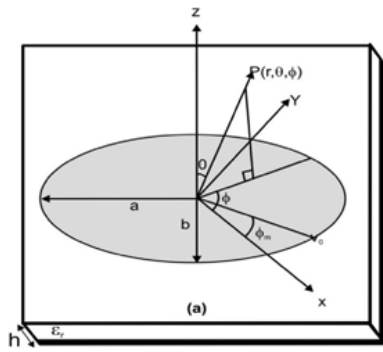


Fig 1: Geometry of microstrip rectangular patch antenna

2.2 Antenna Structure

The configuration and coordinate system of a planar array antenna considered are depicted in figure 2. It consists of 16 identical elements with separation $d_x = d_y = \lambda$ cm printed on RT-duroid substrate of thickness 'h' and substrate permittivity ϵ_r . The length and width of rectangular patch are 'a' and 'b' respectively. The array elements which are poisoned along x-axis are separated by d_x and along y-axis are separated by d_y (Balanis, 1982) [3].

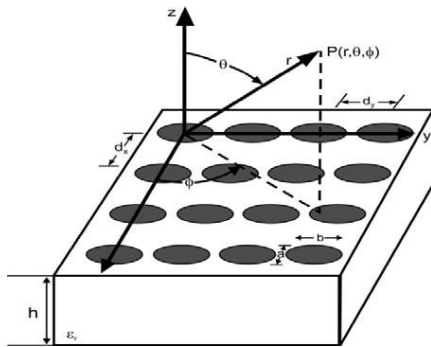


Fig 2: Geometry of 4 x 4 array microstrip rectangular patch antenna

3. Results and Discussion

The radiation patterns and radiation parameters have been plotted and calculated respectively. A 16 elements planar array of ellipse patch of oblate radius 0.61 cm and prolate 0.61 cm, is printed with elements separation $d_x = d_y = 3$ cm on RT-duroid substrate of $\epsilon_r = 2.33$ and height $h = 0.165$ cm.

Radiation Patterns

The far field radiation patterns in the Oblate mode are obtained for E plane ($\phi = \pi/2$) and H plane ($\phi = 0^0$).

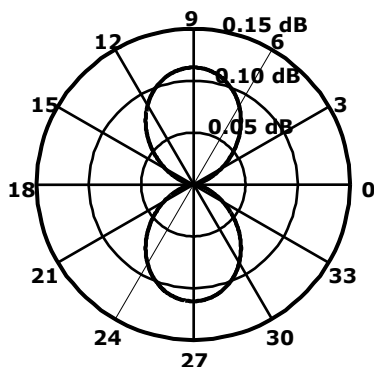


Fig 3: Radiation pattern of elliptical patch antenna in E-plane ($\phi = \pi/2$)

The total field pattern $R(\theta, \phi)$ is generally obtained by the relation: $R(\theta, \phi) = |E_\theta|^2 + |E_\phi|^2$. The planar array pattern is computed for source frequency $f_r = 10$ GHz with progressive phase excitation $b_x = b_y = 0$. The patterns of E plane, H plane and planar array are shown in fig. 3, 4 & 5 respectively.

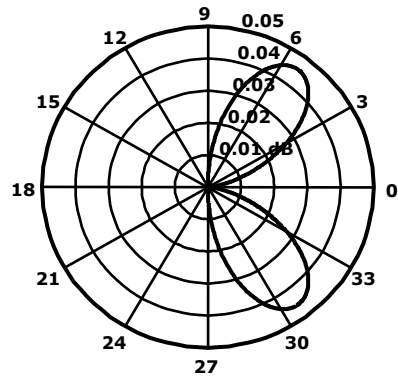


Fig 4: Radiation pattern of elliptical patch antenna in H-plane ($\phi = 0^0$)

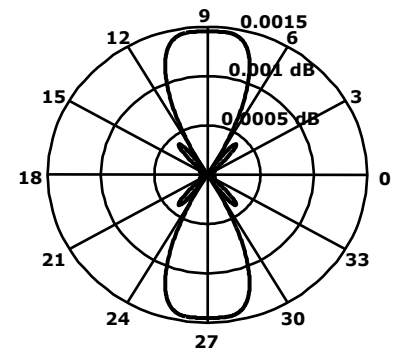


Fig 5: Variation of $R(\theta, \phi)$ for 4x4 elliptical microstrip array configuration

Radiation Parameters

All important parameters like bandwidth, directive gain, total impedance and quality factor of circular and elliptical microstrip patch antenna printed on RT-duroid has been calculated and tabulated in table 1.

4. Conclusion

Elliptical patch geometry is perhaps least analyzed regular shape geometry due to involvement of higher and complex mathematics. The theoretical treatment of the elliptical patch antenna (EPA) has been tried by various numerical techniques. In the present work the full wave analysis has been applied to investigate the elliptical patch antenna but due to the mathematical complexities of Mathieu's and modified Mathieu's function, the analysis stopped after some even important results. The involvement of these functions makes mathematics of elliptical patch geometries extremely difficult. After this the Method of Moment has been applied with cavity model of elliptical patch antenna. Theoretical results of elliptical patch antenna have been developed by Method of Moment analysis with the help of cavity model. Radiation field patterns for E-plane, H-plane and array configuration have been plotted for oblate form. There are very similarities between the field expressions, radiation patterns and radiation parameters of circular and elliptical geometries. The calculated radiation parameters of elliptical microstrip antennas have been tabulated and

compared with the results calculated for circular microstrip antenna with same configuration and frequency range.

Table 1: Comparison of characteristics of circular and elliptical microstrip patch antenna printed on RT-duroid

Radiation Parameters	Values	
	Circular Patch	Elliptical Patch
Radius /Oblate (a)	0.51 cm	0.61 cm
Prolate (b)	--	0.51 cm
Bandwidth (BW)	2.99 %	2.84 %
Directive Gain (D_g)	6.59 dB	8.37 dB
Q. Factor (Q_F)	13.62	14.35
Total Imped. (Z_{in})	124ohms	136ohms

5. References

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